CHAPTER 12

OTHER FACTORS TO BE CONSIDERED

Section I. Effects of Locks and Dams on Sediment Movement

12-1. Spillway Operation. The movement of sediment in a channel with navigation locks and dams is affected by operation of the spillway gates and varies with river discharge and location within the pool. When discharges are such that normal upper pool is maintained or exceeded without gate control, open-river conditions prevail and the spillway gates are in a raised position. With this condition, the water-surface slope is nearly parallel to the bed with sediment movement occurring through the entire pool and through the dam over gate sills having crest elevation at or near the elevation of the streambed. As the discharge decreases to below the maximum required to maintain a normal upper pool elevation at the lock, the gates are closed in increments as required to maintain the minimum level of the pool. Closure of the dam gates produces a backwater effect and a reduction in the velocity of currents moving toward the dam. Because of the reduction in velocity, deposition begins at the dam and moves progressively upstream as the backwater effect continues to increase with decrease in river discharge and increase in the amount of gate closure. While deposition is occurring in the lower reach of the pool, sediment movement in the upper reach could continue until the backwater effect extends upstream to the next dam.

12-2. Hinged Pool Operation. The point of deposition will vary with river discharge and the amount of gate closure. If the discharge remains relatively constant for a considerable period of time, sufficient deposition could occur at a given location to require maintenance dredging in critical reaches. The location of deposition or scour can be controlled to some extent by variation in the normal pool level during critical flows. This operation, referred to as "hinged pool operation," would involve lowering the pool several feet (usually 2 to 5 feet) below normal upper pool during critical flows where adequate depths are available at the upper end of the pool and then raising the pool to extend the backwater effect above the critical reach. The amount of lowering should also consider the effect of the increase in velocities on navigation. This operation is also used in anticipation of powerhouse releases or rises in river stage and discharge upstream; this maintains water level at or below normal upper pool level longer and reduces the amount of stage variations.

12-3. Open-River Conditions. When the river discharge increases to above that required to maintain the minimum pool level, open-river conditions prevail and there is movement of sediment through the entire pool; the movement of sediment is generally greater in the lower reach because of the reduced cross-sectional area produced by the deposition. During open-river flows, deposition occurring over the gate sill and within the stilling basin should not affect gate operation since velocities over the sill are increased as the gates are closed. Since movement of sediment toward the dam varies inversely with the amount of gate closure, there would not be any serious tendency for sediment to deposit against fully or partially closed gates.

12-4. Depths in Upper Lock Approach. Although the lock and dam structures are used to maintain a minimum pool level some 20 feet or more above the natural low-water plane, depths in the upper lock approach cannot always be maintained without regulating structures (fig. 12-1).

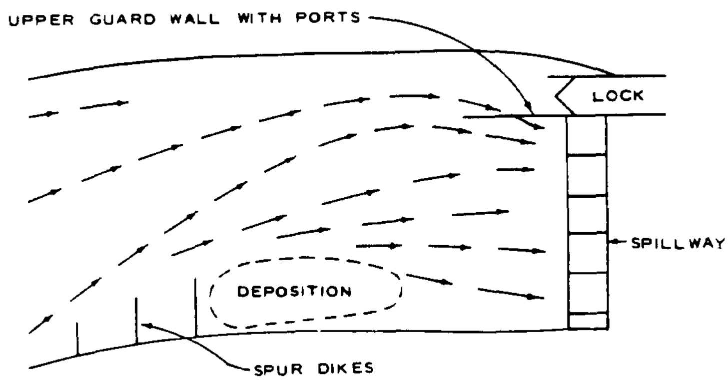

Figure 12-1. Training structures designed to maintain depths in the upper lock approach

This is particularly true if the alignment of the channel is such that there is a natural tendency for shoaling along the lock side of the channel. Manipulation of the gate opening would generally be ineffective in removing the shoal since most of the sediment movement occurs during open-river conditions. The tendency for shoaling on the lock side of the channel can be determined by studying the channel configurations before the structure is built and investigating the tendency of the channel to cross toward the opposite side of the river.

Section II. Harbors and Mooring Areas

12-5. Location. The development of commercial traffic on inland waterways will depend to a considerable extent on the availability of adequate mooring areas, fleeting areas, and docking and harbor facilities. In many cases, docking and harbor facilities are provided as part of the development or improvement of the waterway for navigation in cooperation with local interest. Unless these facilities are carefully planned, hazardous conditions could exist, particularly when placed along the bank adjacent to the main channel of the waterway. As a general rule, these facilities should not be placed close to lock approaches, on the concave side of a sharp bend, just upstream of a bridge, or where the channel tends to be of limited width.

12-6. Inland Harbors. When suitable areas for docking facilities along the streambank are not available, harbor areas are provided inland from the channel. These areas might be offsets in the bank line, lower reaches of tributary streams, old bendway channels, or an excavated area landward with a connecting entrance canal. The design of the harbor facilities should consider the traffic using the facilities, currents, ice and debris, movement of sediment, and effects of changes in river stages.

12-7. Harbor Entrances. When an opening is provided in the bank line, there is an abrupt change in the width of the channel and a tendency for shoaling in the expanded area. Shoaling in harbor areas or entrances to harbors can be a serious problem because of dredging cost, lack of suitable disposal areas, environmental factors that have to be considered, and interference with traffic. The tendency for shoaling will be greater when the entrance is placed on the convex side of a bend and increases with an increase in the size of the opening in the bank line.

12-8. Effects of Currents. Normally, tows entering the harbor area have to make a turn from the river channel. A downbound tow making the turn toward the entrance will tend to have its stern rotated downstream by the currents and could be in danger of hitting the banks of the entrance canal. When velocities are substantial, it might be necessary for downbound tows to turn around and approach the entrance from downstream. Flaring of the entrance to provide for both upbound and downbound tows would increase the tendency for crosscurrents in the entrance and the tendency for shoaling (fig. 12-2). In sediment-carrying streams, it is generally better to angle the entrance channel toward the downstream (fig. 12-3). With this alignment, the tendency for shoaling will be reduced and upbound tows can approach the entrance from along the adjacent bank in a direction nearly parallel to the alignment of the currents. When structures are required to prevent shoaling, it is generally not practical for downbound tows to enter the harbor without reversing their direction (fig. 12-4).

12-9. Old Bendways. Development of harbors in old bendway channels bypassed by a cutoff will generally require the closure of one end of

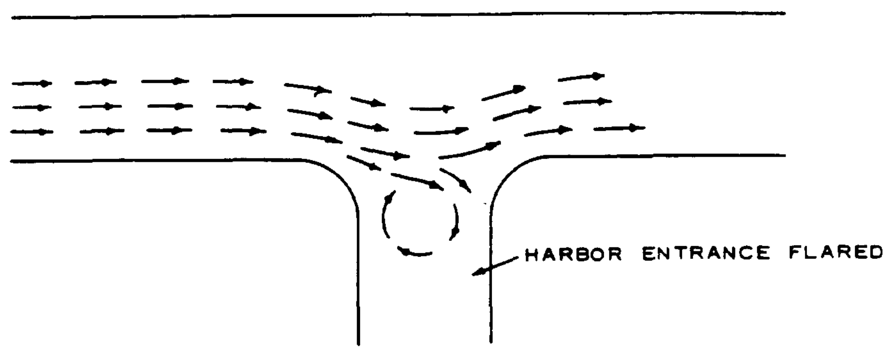

Figure 12-2. Currents with flared entrance

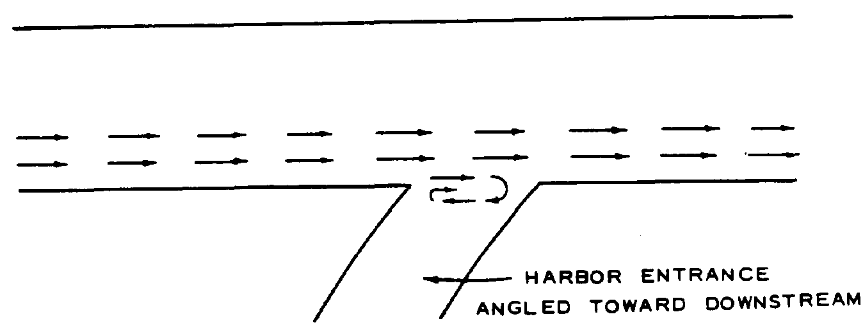

Figure 12-3. Currents with entrance angled downstream

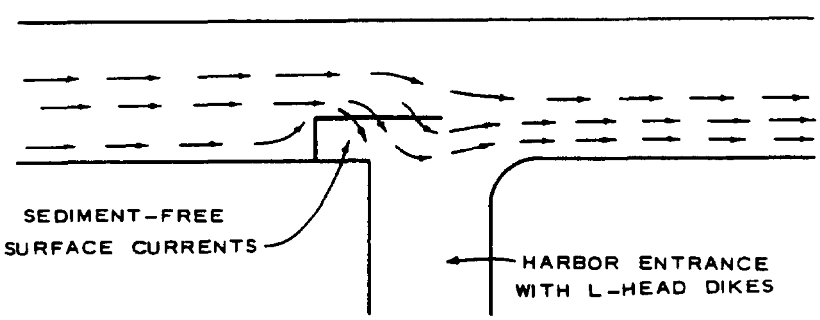

Figure 12-4. L-head dike used to reduce shoaling in harbor entrance

the channel (usually the upper end) and structures such as stepped-up dikes, L-head dikes, or wing dikes similar to those used in lower lock approach to reduce or eliminate the tendency for shoaling in the entrance at the lower end of the bendway (fig. 7-1).

12-10. Harbor Design Guidance. The principal features to be considered in the design of harbors are entrance and access channels, turning basin, mooring facilities, and loading and unloading facilities. Factors to be considered in entrance location and configuration are the effects of currents, wind, and shoaling problems, traffic congestion, visibility, direction from which most of the traffic is expected to approach the harbor, and maneuvering required. Access channels should provide the width needed for safe transit of the traffic anticipated based on one-way or two-way traffic in straight or curved channels, currents caused by variations in river stages, tides, local drainage, wind effects, and structures or equipment moored along the banks. Turning basins should be large enough to permit the size tows using the harbor to change directions without endangering equipment moored in the harbor or harbor facilities and without excessive maneuvering. The size and shape of the turning basin should be a matter of judgment based on the size of tows using the harbor, type of commodity handled, traffic congestion anticipated, safety, and efficiency.

Section III. Ice Problems

12-11. Effects on Navigation. Navigation on some of the northern waterways has been suspended annually and others have been affected periodically because of the heavy ice accumulations and their effect on traffic and the operation of facilities such as locks and dams and spillways. However, in recent years, the navigation season on some waterways has been extended and efforts will be continued to provide year-round navigation insofar as practical.

12-12. Effects on Structures. In addition to its effects on navigation, ice can cause damage to training and stabilization structures and mooring and docking facilities along the banks of the stream. Ice accumulation in lock approaches tends to block the entrance to the locks and could affect the operation of the lock gates. When a guard wall with ports is provided, ice and drift will tend to move into the lock approach and be trapped between the guard wall and adjacent bank and might have to be moved out or passed through the lock before traffic can be accommodated. Ice accumulation against partially closed spillway gates could render the gates inoperable and could result in flooding or overtopping of the dam and lock walls. The same effect could occur when ice jams or gorges develop in reaches between locks and dams or in open-river channels.

12-13. Design Considerations. The probability of ice formations and the movement of ice and debris should be considered in the design of spillways, locks and dams, channel alignment and dimensions, and necessary training and stabilization structures. Some of the provisions that might be considered are:

a. Air bubbler screen or ice boom designed to divert ice and debris away from the lock approach.

b. High air flow screens in gate recesses.

c. Lock emergency gates designed and maintained for passing ice and debris.

d. Means of preventing ice formation in the area of the lock miter gates, the lock filling and emptying valves, lock walls, and emergency bulkhead latching devices.

e. Protection from excessive scour downstream of the spillway during uneven operation of the gates to pass ice.

f. Heating cables or pipes in lock walls.

g. Chemical coating of lock walls to reduce ice adhesion.

h. Elimination of sharp bends in the channel and constricted reaches where ice jams or gorges might develop.

i. Provisions for raising and lowering of the upper pool above and below the normal pool level during low flows.

Section IV. Increasing Capacity of Existing Waterways

12-14. General. The capacity of existing waterways to handle modern traffic is often limited by the sizes of the available locks, lock operating facilities, navigation conditions in lock approaches, effects of adverse currents, limited channel dimensions and bridge clearances, location of docks and tow assembly areas within the approaches, and need for passage of small boats and pleasure crafts. Considerable increase in the capacity of some waterways can be accomplished by eliminating hazardous conditions, need for excessive maneuvering, and need for the temporary closure of the project because of accident or maintenance.

12-15. Modification of Locks. The sizes of locks and conditions in the lock approaches can be major factors affecting the capacity of a canalized waterway. When the locks are too small to accommodate the size tows using the waterway, multiple lockages and in some cases changes in the makeup of the tows will be required. The capacity of existing locks can often be increased by: modifications that would reduce lock filling and emptying time and time required to open lock gates; modification of lock auxiliary walls; providing accessible mooring facilities for waiting tows or sections of tows that cannot be accommodated in the lock; providing towing mechanisms or tenders to assist tows or section of tows through the lock; eliminating adverse conditions in the lock approaches; providing special facilities for pleasure crafts; and traffic regulation. Other alternates are enlarging the existing lock or construction of an additional lock large enough to accommodate existing traffic and traffic that can be reasonably anticipated.

12-16. Lock Approaches. The capacity of existing locks can be increased in many cases by modifications designed to eliminate hazardous conditions in the lock approaches and the effects of adverse currents which require considerable maneuvering of the tows before a satisfactory approach to the lock can be made. Safe navigation conditions in the approaches would permit the passage of larger and heavier loaded tows up to the full capacity of the lock and reduce downtime that might be caused by accidents. The modifications that can be made in the lock approaches and benefits obtained will depend on conditions at each lock and might include one or more of the following: realignment of the channel upstream and downstream; training structures designed to improve the alignment and velocity of currents; additional maneuver area; modification or extension of lock guide or guard walls; elimination of obstruction within the approach channel; mooring or protective cells; elimination of ice and debris from the lock approach; and reduction or elimination of any adverse effects from lock emptying and filling or powerhouse operations. Model studies can be invaluable in determining the conditions affecting navigation and in developing the most effective and economical solutions.

12-17. Lock Replacement or Addition. The capacity of some waterways cannot be increased substantially without the enlargement of the existing locks, construction of additional locks, or complete replacement and/or relocation of some of the lock and dam structures. The enlargement of existing locks would not be practical in most cases where traffic has to be maintained or where the existing structures have deteriorated to such an extent that cost of repairs or rehabilitation would be excessive. In such cases an additional lock or a complete replacement structure would be required.

12-18. Modification of Channel Dimensions. The capacity of existing channels is affected by the dimensions and alignment of the channel, velocity and alignment of currents, shoaling tendencies, and obstructions such as limited bridge clearances and accumulations of ice and debris. The draft of tows using a waterway will depend to a large extent on the controlling depths available. Increasing depths in critical reaches can increase tonnage considerably by accommodating tows with greater draft. The width of a channel will have some effect on the size of tows and whether one-way or two-way traffic can be accommodated. The capacity of a waterway can often be increased by increasing the width of the channel, particularly in bends and in reaches where sharp turns have to be made or maneuvering is required.

12-19. Current Alignment. The alignment of the channel and adverse currents can cause delays and contribute to accidents. Improvement of the alignment of the currents with respect to the alignment of the channel can eliminate the need for maneuvering and provide for adequate sight distance.

12-20. Bridges. Bridges and other structures with limited vertical and horizontal clearances can contribute to accidents and delays. Capacity and safety of the waterway can be improved in some cases by realigning the channel approaching the bridge, improving the alignment of currents upstream and downstream of the bridge, use of guide walls or fenders on the piers, or modification or replacement of the bridge.

Section V. Special Design Features

12-21. Special Features. Some special features that could have a significant effect on navigation conditions, operation and maintenance of the waterway, and/or cost of the project are discussed below.

12-22. Debris Control. Substantial amounts of floating debris can hinder lock operation and present a hazard to navigation. The usual debris disposal method is to pass it over the spillway which only presents a rehandling problem downstream. An alternative is to provide land disposal areas for debris at each project. Booms and workboats can direct debris to a shore pickup area. Air bubblers have been used successfully to keep debris out of lock miter gate recesses.

12-23. Standardization. Considerable economy can be achieved by standardization of some features of a project which would reduce design and procurement cost and require fewer replacement parts. An example is the Red River Waterway where spillway gate widths are the same for Locks and Dams 2, 3, 4, and 5. This allows interchangeability of spare tainter gates. Also, fewer maintenance bulkheads are needed to service the four projects.

12-24. Emergency Closure. All projects should have a contingency plan for access to spillway gates and lock gates so closure can be made in case of an accident. This closure is particularly important at high-lift locks and where there exists a high risk to downstream users. Closures can be made by stoplogs placed by cranes. If closure is desired under flow conditions, the crane must operate from a spillway bridge or lock wall. Also, bulkheads must be designed for placement in flowing water. If closure is to be made after the upper pool is lost, bulkhead placement can be made by a barge-mounted crane. This closure method requires that the upper lock gate sill and approach channel be lowered to an elevation where an upbound floating crane can reach the upstream dam face. Other closure methods for locks could be: inflatable dam, submerged tainter gate, or submerged vertical-lift gate.

12-25. Impact Barriers. During the period 1968 to 1977 there were in excess of 350 reported collisions of barges with miter gates. Both repair costs and lost navigation benefits were considerable. One method of reducing the chance of these collisions is to provide impact barriers. Barriers should be provided at locks when a gate failure would cause loss of life or the repair cost and lost navigation benefits would justify the barrier cost. If barriers are considered necessary, they should be designed to withstand the impact of a full-size loaded tow traveling at a reasonable speed. Some of the provisions for the prevention of accidental damage to miter gates that should be considered are as follows:

a. Double Lock Gates. Double gates have been the traditional safeguard but wire rope or nylon net barriers should be considered. High-lift locks could have a lower guard miter gate with the bottom portion removed. This would allow returning the guard gate to the recessed position when the tow dropped below the gate. This type of gate would not require any expensive lock lengthening.

b. Concrete Beam. Another concept is to build a concrete beam across the lock, downstream from the lower miter gate. The gate would seat against this beam in the mitered position. When the chamber is empty, the gates would open and the tow would pass under the beam when exiting the chamber. If a barge collided with the lower gate, the impact load would be transferred to the beam with little damage to the gate. The beam could also serve as a structural member and a bridge for equipment movements.

c. Lift and Submergible Gates. A properly designed vertical-lift gate and submergible tainter gates can withstand a much greater collision than a miter gate and may be attractive when compared with a miter gate plus impact barrier combination.

12-26. Water Conservation. The competing interest for water can often provide a compelling case for conserving lockage water. Some water conservation measures for a navigation project with locks and dams could be:

a. Water Saving Basins. Provide a basin adjacent to the lock that can be filled with emptying water from the upper elevation of the chamber. When the basin is full, the lock discharge water is directed to a lower basin or into the lower approach. During filling, the water is drained (by gravity) into the lock thus saving water (volume equal to the basin) from being withdrawn from the upper pool.

b. Intermediate Gates. The chamber can be divided into half or thirds by providing intermediate closure gates between the upper and lower gates. This conserves water by filling only a part of the chamber when short tows or pleasure craft lock through. Modifications to the filling and emptying system are needed to assure safe and efficient operation for both partial chamber or full chamber lockages.

c. Pumpback. Lock water can be returned to the upper pool for reuse by pumps.

12-27. Mooring Facilities. Mooring facilities should be provided upstream or downstream from a lock, if waiting barges would present a hazard to navigation or the project. These structures could be sheetpile cells or ported walls with rings or mooring bits or grappling hooks anchored on the bank. Locks with adverse currents or long waits for lockage should consider mooring facilities.

Section VI. Effects of Surface Waves

12-28. Waves Generated by Traffic. Surface waves of substantial size can be generated by tows and by recreational boats. Waves generated by traffic can adversely affect equipment and barges moored along the banks and the stability of the material forming the banks. The size of the waves reaching the bank or moored equipment will vary with the distance from the bank or equipment that the tow passes; the type, size, and draft of the tow; speed of the tow; and depth of the channel. Waves will tend to increase hawser stresses of barges moored along the bank and could cause them to break loose and endanger traffic or structures downstream. The size of waves and their effects can be reduced by limiting the size and speed of the tows using the waterway and by preventing tows from moving within a fixed distance from the banks or moored equipment. Fast-moving small recreational boats passing close to the banks or mooring areas can produce waves that are more objectionable than those created by most tows.

12-29. Wind Waves. Waves generated by wind would depend on wind velocity and the length of fetch in the direction of the wind. Except during storms or atmospheric disturbances, wind waves do not constitute a hazard to navigation in rivers and canals but can have a serious effect in large lakes and bays with long fetches and high prevailing winds. Winds can also affect the maneuverability of tows, particularly tows with empty barges. Wind blowing in an upstream direction will tend to produce a higher wave than when blowing toward the downstream. Wind waves on rivers and canals are usually small but can be continuous for long periods and can have some effect on bank erosion.

12-30. Prototype Measurements. The size of traffic-created waves on the Ohio River and some of their effects on the environment were measured and evaluated by the U. S. Army Engineer District, Huntington, with the assistance of the U. S. Army Engineer Waterways Experiment Station (WES) and special consultants. These measurements covered a large number of vessels of different sizes moving upstream and downstream at different speeds and distances from the bank line. Although a final report on the results had not been completed, preliminary analysis and evaluation of the results indicated the following general conclusions:

a. The size of waves approaching the bank increased with the size, draft, and speed of the tow and decreased with increase in the distance from the bank.

b. Waves created by small recreational vessels can be as large or larger than those created by towboats.

c. Wave sizes tended to be greater with greater depth (during high water) and tend to become smaller approaching a sloping bank or beach than when approaching a vertical bank.

d. The effects of traffic on the physical and biological components of the Ohio River were generally insignificant in comparison with ambient and natural changes. Changes produced by traffic were generally small and of short duration. The largest wave measured had a height of

3.3 feet produced by a towboat with nine loaded barges moving downstream at a speed of about 12 miles per hour and 200 feet from the water's edge. The measurement was made about 15 feet from the water's edge where the depth was about 5.5 feet. It should be noted that the Ohio River is wider and deeper than most streams or inland waterways. Conditions in restricted waterways could be considerably different.